RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Electrodialysis (ED) and Electrodialysis Reversal (EDR)

Electrodialysis (ED) is an electrochemical process in which ions migrate through ion-selective semipermeable membranes as a result of their attraction to two electrically charged electrodes. ED is able to remove most charged dissolved ions.

1.0 Applicable Contaminants

ED/EDR is an EPA BAT for the following contaminants: barium, nitrate and nitrite, selenium, and TDS.

2.0 Description of Technology

Electrodialysis is a process that depends on the principal that most dissolved salts are positively or negatively charged and they will migrate to electrodes with an opposite charge [2]. Selective membranes that are able to allow passage of either anions or cations make separation possible [2]. ED uses these membranes in an alternating fashion to create concentrate and product streams.

The anions are able to pass through the anion-selective membrane, but are not able to pass by the cation-selective membrane, which blocks their path and traps the anions in the brine stream (Figure 1). Similarly, cations move in the opposite direction through the cation-selective membrane under a negative charge and are trapped by the anion-selective membrane [2]. An ED unit is able to remove from 50% to 94% of dissolved solids from a feed water, up to 12,000 mg/l TDS [3,7]. Voltage input and process configuration (number of stacks or stages dictates the viable percent removal. TDS removal is generally limited by economics. The cost of ED increases as the feed water TDS increases. The typical operating conditions are 1,200 mg/l TDS, high hardness and high silica [4].

A typical ED system includes a membrane stack with a number of cell pairs, each consisting of a cation selective membrane, a demineralized flow spacer, an anion selective membrane, and a concentrate flow spacer. Compartments for the electrodes are at opposite ends of the stack. The electrodes are continually flushed to reduce fouling or scaling.

Recycling the concentrate stream and discharging concentrate to waste, or blowdown, is common and called feed-and-bleed mode [2]. This is necessary because of the fact that there are sharp differences in flow rates between the product and brine streams. Diluate flow is about 10 times the flow of the brine stream; this difference in flows creates pressure imbalances, requiring concentrate recycle [5].

Membranes are usually made out of cation- or anion-exchange resins made into sheet form. ED spacers are made out of HDPE, and the electrodes are composed of an inert metal. Membrane selection is based on careful review of raw water characteristics.

Electrodialysis Reversal (EDR) is similar to ED but the polarity of the electrodes is regularly reversed, thereby freeing accumulated ions on the membrane surface. This process minimizes the effect of inorganic scaling and fouling by converting product streams into waste streams [6]. This process requires additional plumbing and electrical controls, but increases membrane life. EDR does not require added chemicals, and eases cleaning as well.

Pretreatment Typical operation requires: the addition of a scale inhibitor to prevent scaling and reduce the LSI below 2.1 in the concentrate stream, residual chlorine concentration of 0.5 mg/L to prevent biological growth, and a cartridge filter (10-20 µm) prior to the ED/EDR system. Air stripping can also be used prior to ED/EDR in order to remove H_2S [6] Also, the feed water must be within the limitations of an ED/EDR system (see Limitations).

Maintenance ED membranes are durable, can run under a wide range of pH conditions (pH 2 – 11), and endure high temperatures during cleaning [4]. They can be removed from the unit and scrubbed if necessary. If operated properly, membranes have an average life of 12 to 15 years [4]. Solids can be flushed out by turning the power off and letting water circulate through the stack. The ED stack must be disassembled, mechanically cleaned, and reassembled at regular intervals. They can also be cleaned using a 5% hydrochloric acid solution [8].

Waste Disposal The concentrate waste stream, electrode cleaning flows, and residuals from the pretreatment process will be a part of a typical waste stream and will require disposal. Common disposal methods include: surface water discharge, evaporation ponds, etc. Spent membranes will also require disposal.

Benefits

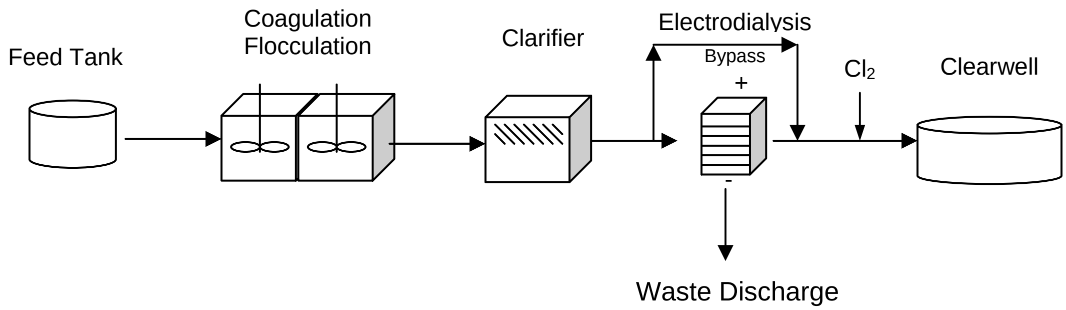
- ED and EDR can operate with minimal fouling or scaling, or chemical addition.
- Low pressure requirements.
- ED and EDR facilities are quieter than RO.
- Long membrane life expectancy.
- Unaffected by non-ionic scalants such as silica [1].
- Low chemical usage for pretreatment[1].
- Ability to treat feed water with higher SDI, TOC and silica concentrations, and more turbidity than RO [1].
- Can operate with up to 0.5 ppm of free chlorine in the feed water to control the biological matter in the feed water [8].

Limitations

- TDS economical up to 10,000 ppm, but often run at waters of 1,200 ppm [6,9]
- pH: 2.0 to 11.0
- TOC: up to 15 mg/l
- Free Chlorine: 0.5 ppm with spikes up to 15-20 ppm
- Turbidity: up to 2 NTU
- Iron (Fe^{+2}): 0.3 ppm
- Mn ($^{+2}$): 0.1 ppm
- H_2S: up to 1 ppm
- SDI: 15 (5 min SDI)

3.0 Example Treatment Train

The conventional EDR treatment train typically includes raw water pumps, debris screens, rapid mix, antiscalant, flocculator, clarifier, gravity filters, EDR membranes, chlorine disinfection, and clearwell storage. Microfiltration (MF) could be used in place of flocculation, sedimentation, and filtration.



4.0 Safety and Health Concerns

- Produces hazardous gasses, such as chlorine, hydrogen, H_2S, etc.
- Electrical hazard

5.0 References

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